Marine Environmental Assessment of a Barachois at Cite La Chaux, Mahebourg

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Report

Marine Environmental Assessment of a Barachois at Cite La Chaux, Mahebourg

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Executive Summary

Cite La Chaux is located near the coast of the village of Mahebourg, in the south east of Mauritius and in the district of Grand port. This district is well known in history, bearing the testimony of the Dutch and the French colonies and Mahebourg waterfront is a famous attraction to many tourists. The geographical location of Cite La Chaux, Mahebourg is GPS position: $20^0$25'03.35''S ; $57^0$42'47.35''E. It is situated near the main road and surrounded by the two species of mangroves namely *Bruguiera gymnorrhiza* and *Rhizophora mucronata* found in Mauritius. The area features a tropical weather, encouraging activities like fishing and recreational activities along the Eastern coasts. However, to prevent illegal fishing in the Mauritian lagoons around that area, the Ministry of fisheries has established a fisheries post known as Mahebourg Fisheries port at the site. The small region around the barachois harbors many fishermen and their families who derives their earnings by exploiting the sea itself. The common fish they sell are 'Guele pave', 'cordonnier', 'vielle rouge', 'poisson corn' amongst others fished around the lagoon of the eastern coast and off-lagoon also.

Benthic surveys showed that the substrate around the barachois was dominated by the presence of sandy bottom covered with a thin layer turf algae and few patches of rocky substratum with few macroalgae density. Patches of corals were observed in the northern part of the barachois, the species *Porites lutea* were the most dominant while other species encountered were *Cyphastrea microphthalma*, *Porites rus* and *Montipora calcarea*.

The main conspicuous invertebrate to have been observed during the survey were the small urchins with the thin and long spines of the *Diadema sp* which were found anchored in between rocks.

Fish surveys revealed the following common fishes encountered during the survey which included the species *siganus sp (cordonnier), Upeneus sp (rouget), Valenciennea sp (cabot), Mugil cephalus (Mullet).* Furthermore, fish surveys revealed that the fish species richness is very low in this region due to fishing practices, low water depth and local population just next to the barachois.

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1.0 Introduction

1.1 Historical Background

The ecosystem studied is a closed system with a physical enclosure made of rocks. This area was once used by the Ministry of Fisheries as a mariculture site for fish with smaller side ponds for culture and/or fattening of fish and crustaceans such as lobsters and crabs. The actual site being studied had a depth that reached 2 meters in the central areas. Today this same site has an average depth not exceeding 1 meter at low tide. This gradually decline in depth has been mainly due to continuous sedimentation and the bed consists mostly of silt deposit. The artificial wall has allowed sedimentation across and deposition within the closed system. In those days the annual catch of fish was in tones and comprised of mainly species like *Rhabdosargus sarba*, *Mugil cephallus*, *Lethrinus harak* and *Siganus sutor*. The edible and commercial crab "carle" once were also very common in this area.

1.2 Survey Logistics

The major items of equipments that have been used to carry out this present survey were as follows:

1. Boat with outboard engines
2. Garmin 60 GPS
3. Mares Dive Computer "Matrix"
4. Underwater still camera
5. Underwater video camera
6. 50 m fibre-glass measuring tapes
7. Underwater slates and pencil
8. Ropes, floats and dead weights
9. HawkEye H22PX handheld depth finder
10. 1m x 1m plastic quadrate

2.0 Methodology

2.1 Survey Sites

The survey was carried out in winter season between June and July 2016 at Cite La Chaux, Mahebourg extending over the Barachois (A) and adjacent lagoon (B) and wetland earmarked (C) as represented in Figure 1 below.

Figure 1: Picture representing the Barachois, Adjacent lagoon area and the connecting wetlands.

Source: modified from google earth

2.2 Surveyed stations

The whole area was divided into three distinct zones as follows:

Zone A: Barachois

Zone B: Lagoon

Zone C: Wetlands

The above mentioned zones were further divided into stations:

Stations	Zones	GPS Locations	Remarks
Station 1	C	20°25'13.87"S ; 57°42'48.72"E	-
Station 2	B	20°24'52.96"S ; 57°42'46.96"E	-
Station 3	B	20°24'55.50"S ; 57°42'59.90"E	-
Stations 4-10*	A	20°25'2.66"S ; 57°42'48.00"E	Down the red line

*The red line drawn in figure 2 represents the 7 equally divided stations (4-10), Station 4 starts from the far west and Station10 is found in the far east.

Figure 2: Picture representing the stations in the Barachois and surrounding areas.

Source: modified from google earth

2.3 Water quality sampling and analysis

The following physico-chemical analysis were performed for each stations: pH, Dissolved Oxygen, Nitrate, Phosphate, Salinity, and Temperature. Samples were taken around 20±10 cm from surface by opening sealed plastic bottles at the appropriate depth. Plastic bottles were used to contain the water samples for laboratory analysis. Temperature, pH, salinity and dissolved oxygen were immediately recorded from the bottle once completely filled. The water samples were stored in cooler box at a temperature below 10°C and in complete darkness during transportation for further analysis such as Nitrate and Phosphate.

2.3.1 Temperature

A glass thermometer was used to analyse the seawater directly on-site from the sampling bottles. (No calibration required).

2.3.2 pH

A pH meter (HANNA, HI 991001) with extended range waterproof pH/Temperature Meter was used to analyse the seawater directly on-site from the sampling bottles. (Calibration was performed using the manual provided).

2.3.3 Dissolved Oxygen (DO)

A DO meter (SPER Scientific DO Pen) was used to analyse the seawater directly on-site from the sampling bottles. (Calibration was performed using the manual provided).

2.3.4 Salinity

A refractometer was used to analyse the seawater directly on-site from the sampling bottles. (No calibration required).

2.3.5 Nitrate and Phosphate

A multi-parameter photometer (HANNA HI83203) was used to analyse the seawater. Samples were taken to a proper location and were analysed (all samples were analysed within 2hours after sampling). Cadmium Reduction method was used for Nitrate analysis while Ascorbic Acid method was used for Phosphate analysis. (No calibration required).

2.4 Sediment sampling and analysis

A total of 3 samples (S1, S2 and S3) of sediment with 3 replicates (R1, R2 and R3) each were collected randomly along the virtual red line as represented in figure 2. They were stored in plastic bags and transported to laboratory where initial tests such as pH and electrical conductivity test were conducted on the fresh samples. The sediments were then allowed to air-dry on a tray for one week and eventually each sample was passed through a 2mm sieve and collected in a clean plastic container for further analysis:

2.4.1 Determination of Organic Matter

Organic matter in the 3 samples S1, S2 and S3 was determined according to the protocol stated by Rowell (1994) with minor modifications. 1g of sediment sample was weighed in a conical flask and 10ml of 5% Potassium Dichromate and 20ml of concentrated sulphuric acid was added. The mixture was allowed to cool and 50ml of barium chloride was added and left to stand overnight. Known concentration of standard solutions containing 0, 2.5, 5, 7.5, 10 and 12.5 mg/ml of carbon were prepared and both standard and sample solutions were read at 600nm using a spectrophotometer. For accurate results, each sample was replicated thrice.

2.4.2 Determination of Total Nitrogen

Total nitrogen in the 3 samples S1, S2 and S3 was determined according to the protocol stated by Rowell (1994) with minor modifications. 0.5g of sample was weighed into the digestion flask and one kjeldahl tablet was added followed by 15ml of concentrated sulphuric acid. The solution was then heated on a digestion rack at a temperature of 380^0C until no charred organic matter remaining. After cooling, the obtained solution was diluted with deionized water and passed through a distillation flask. The distillate was then titrated with 0.01M of hydrochloric acid. For accurate results, each sample was replicated thrice. The concentration of total nitrogen in the sediment was eventually calculated using the formula provided by FAO Soils Bulletin (1980).

Total nitrogen (mg/100g of soil) = (ax14)/P, where a is HCl/ml and P is soil/g.

2.4.3 Determination of Sulphur

Sulphur in the 3 samples S1, S2 and S3 was determined according to the protocol stated by Rowell (1994) with minor modifications. 25g soil was weighed and 1g of activated charcoal was added followed by 50ml of Calcium chloride. The mixture was placed on an automatic shaker for 1 hour

and then filtered. 1ml of the filtrate was diluted with 39ml of deionized water and used to determine the concentration of Sulphur in the sediments. Known concentration of standard solutions containing 0, 5, 10, 20, 30, 40 and 50 mg/ml of sulphur were prepared and both standard and sample solutions were read at 480nm using a spectrophotometer. For accurate results, each sample was replicated thrice.

2.2.4 Determination of Total Phosphorus

Total sulphur in the 3 samples S1, S2 and S3 was determined according to the protocol stated by Rowell (1994) with modifications. The weight of the crucible was taken prior to ashing. The crucible was then half filled with sediment and their weight was taken again and then placed in a hot furnace and initially ashed at 300^{o}C for 8hours. The weight recorded before ashing and after ashing at 300oC was used for the determination of total carbon in the sediments.

The sediments were again ashed at 500^{o}C for 8hours and after cooling 0.5g of ashed sediment was mixed with 15ml of concentrated hydrochloric acid in a crucible and placed in a sand bath at 100^{o}C. After drying, 5ml of concentrated Nitric acid was added and heated. After the acid digestion, the content was diluted with deionized water and filtered. 2ml of the filtrate was mixed with 8ml of Ammonium molybdate and 8ml of Ascorbic acid and allowed to stand for 30min. Known concentration of standard solutions containing 0, 1, 2, 3, 4 and 5 mg/ml of phosphorus were prepared and both standard and sample solutions were read at 880nm using a spectrophotometer. For accurate results, each sample was replicated thrice.

2.2.5 Sampling and determination of Heavy Metal

The sediment sample was first oven-dried at 70 °C until constant weight was reached. All laboratory equipment's used were carefully clean to avoid cross contamination with other samples. In a crucible, 2 grams (record to the nearest 0.01 gram) of sediment was taken. Then 10 ml of water was added and a stirring rod was used to pulverize the sample. Concentrated Nitric acid (HNO_3) was used for the digestion of the sediment sample. 5 ml of HNO_3 was added to the sample and allowed to cook in a sand bath uncovered for approximately 15 minutes in a fume hood at 60 °C before dryness. Following to this, another 5 ml of HNO_3 was added to the sample and the crucible was covered with a watch glass and samples were gently reflux. When most of the bubbling has stopped, 2 ml of HNO_3 was added, covered and heating continued. The same step

was repeated for another 2 ml portion of HNO_3. The crucibles were removed from the sand bath and allowed to cool at room temperature. Another 2 ml of HNO_3 was added and sample were gently warmed while uncovered for several minutes. The watch glasses and stirring rods used were rinsed two times with water and the rinsing was collected separately in a 100 ml beaker. The solutions were filtered through filter paper placed in a glass funnel directly into a 100 ml volumetric flask. The crucibles were rinsed twice and the rinsing's were poured into the funnel containing whatman filter paper (125 mm). The solutions were diluted and marked to the line of the volumetric flask and were mixed for further analysis atomic absorption spectroscopy (AAS). Each metals were detected at a specific wavelength and using a specific lamp. The selected heavy metals were determined by the atomic absorption spectrometer with flame type air-acetylene at particular wavelength. Chromium and lead were analysed by the flame type nitrous oxide-acetylene. Arsenic and mercury were determined by the hydride system.

2.5 Benthic Survey

Given that the site is very shallow with a maximum water depth of only 1m at low tide, we not only surveyed the stations but also the whole Barachois first using the line transect intercept (Loya, 1978; Mundy, 1991; English et al., 1997; Leujak and Ormond, 2007) and visual assessment. The survey methods used in the present survey has been modified from the standard methods described in English et al. (1997). Surveys at each station involved firstly a swim over the survey area to determine a representative location for the surveys transect lines. Each site was surveyed for coral and substrate cover, fish populations, invertebrates and flora. The fish surveys were conducted over 50m while the benthic surveys were conducted over 20m. Both surveys were conducted using the same transect lines, with the benthic surveys being in the first 20m of each line. Three replicate survey lines were deployed randomly but in parallel at each station such that they do not overlap. Due to very shallow water, 50m distance long were virtually assessed biodiversity.

The following survey requirements for each station were met, except where indicated otherwise:
General environmental parameters of each station:

- 3 x 50m fish identification and abundance surveys.

- 3 x 20m benthic line-intercept transects surveys for coral and substrate identification, species abundance and health surveys, including a general description of the area.
- Flora identification and abundance survey along the 20m benthic survey lines.
- Conspicuous invertebrates identification and abundance survey over 50m of each transect line

2.6 Fish Surveys

The fish surveys were conducted at each station and over the whole Barachois area. Due to very shallow water at the site, fish surveys were conducted while snorkeling and visual assessment. The observer first waited for 5-15 minutes after deploying the transect line whereby possible before starting the actual counting survey so as to allow fish to resume their normal behavior. Divers then conducted the fish survey along each of these transects, giving a total of 3 surveys at each station. The survey was conducted as a single pass along the transect line, and not broken down into smaller units. Fish were identified to species level. Notes were taken if any endemic species were encountered.

2.7 Conspicuous invertebrates survey

Conspicuous invertebrate species and other life-forms were recorded over the whole Barachois by visual assessments as well as 1m x 1m quadrats. Most of the invertebrates were later identified using Richmond (1997) and Debelius (1998).

2.8 Underwater Photographs

In this report, representative pictures have been provided with the objective to give a general impression of the site and at the same time to better illustrate the substrate cover for the area. The pictures also contain some of the coral, fish and any other marine species encountered during the surveys.

3.0 Results and Discussion

3.1 Marine water quality

The results of physical and chemical parameters measured at the various stations are given below. Some of the data were referenced against available coastal water quality requirements from the Guidelines for coastal water quality requirements for various categories Govt. Notice No. 620 0f 1999 9CWQG *(Annex 1)*.

Table 1.0: Marine water quality results for the different stations

Date - 24.06.16							
Station	**Zone**	**pH**	**DO mg/L**	**Salinity ‰**	**T °C**	**Nitrate mg/L**	**Phosphate mg/L**
1	C	7.8	3.2	37	24	2.5	0.25
2	B	8.1	4.8	35	24.1	0.2	0
3	B	8.1	4.5	35	24.1	1.8	0.02
4	A	8	5.9	36	24.3	2.6	1.23
5	A	8.2	4.6	36	24.3	0.6	0.01
6	A	8	5	36	24.2	1.2	0
7	A	8.2	5.6	36	24.2	2.2	1.42
8	A	8.1	5.3	35	24.3	0	0
9	A	7.9	5.1	36	24.3	1.4	0
10	A	7.9	4.3	36	24.2	3.5	1.12
		Guidelines Category A / Class A2 (Natural Areas)					
		7.0 - 9.0	>2	-	Ambient	1	0.1

3.2 Sediment Quality

3.2.1 pH and Electrical Conductivity

Table 2.0: pH and Electrical Conductivity results

Fresh Samples	S1	S2	S3
pH	**8.23**	**8.29**	**8.27**
Electrical Conductivity (mS)	**2.93**	**3.83**	**2.69**

3.2.2 Total Sulphur

In water Sulphur predominantly exist as sulphates. With an average concentration of 2700 mg/L, sulphate is the third most common species in seawater, after Na and Cl (Hem 1992). Sulphates are considered a less toxic element although present in relatively high level (>1000 mg/L) but it may cause adverse effects in some aquatic species and catharsis and gastrointestinal irritation in human. The sample analysed (Table 2.0) indicates very low concentrations within the threshold (<500 mg/L).

Table 3.0: (Total Sulphur content from 3 samples sediment)

Samples	S1	S2	S3
Final concentration (mg/L)	**161.58**	**129.90**	**137.82**

3.2.3 Total Organic Carbon

Total organic carbon (TOC) and total nitrogen (TN) content, in soils and sediments are important parameters to assess the environmental status of terrestrial and aquatic ecosystems. The soil and sediments organic carbon and nitrogen are mainly derived by decomposition of the plants and animals or plankton or anthropogenic sources such as chemical contaminants, fertilizers or organic rich waste and leaching. The sediments TOC and TN ratios can be used as biomarkers, to distinguish the marine or terrestrial sources of organic matter as well as aerobic/anoxic and sulfur reduction conditions and thus give a qualitative indication of the redox status.

Table 4.0: Percentage of Total Organic Carbon by dry ash method

Samples	Weight after 500°C/g	Total Carbon/g	Organic carbon/g	Inorganic Carbon/g	% Total Organic Carbon
S1	25.76	1.34	0.069	1.271	0.268
S2	28.04	1.38	0.06	1.32	0.211
S3	27.77	1.35	0.069	1.281	0.248

Table 5.0: Concentration of Total Organic Carbon in sediment

Samples	S1	S2	S3
Final concentration (mg/mL)	0.69	0.60	0.69

The Organic Carbon level was normal, that is, below 0.5% which is indicative of shallow seas. Thus, the actual ecosystem shows no evidence of past eutrophication events and thus indicate less leaching from coastlines.

3.2.4 Total Nitrogen

Nitrogen is present in marine system in various forms with nitrate being the principle form of fixed dissolved inorganic nitrogen. As photosynthetic organisms can assimilate dissolved organic nutrients, there has been a growing interest in dissolved organic nitrogen (DON). Indeed, nitrogen has a great contribution to the nutrient cycle. The atmospheric nitrogen is fixed to ammonium by nitrogen-fixing bacteria in soil and aquatic systems. The ammonium (nitrates and nitrites) is then used by crops and animals. When decayed the different forms of nitrogen are released back to soil and marine environment.

Similar to phosphate, any disruption in nitrate normal threshold value in sea water will lead to a destabilized marine ecosystem. For instance, a high level of nutrient would cause eutrophication and a low concentration of nitrate would be the limiting factor for growth of phytoplankton. Concerning sediments, the total nitrogen is an important component as it can be used to distinguish between marine and terrestrial sources of organic matter, as pollution indicators and assessing factor sediment quality. It had been shown that the absence of Dissolved Inorganic Nitrogen (DIN), the Directed Ortho Metalation of benthic community is accelerated. In contrast, a high occurrence of DIN concentration increased the microbial breakdown of organic material. In summation, the availability of DIN in sediment enhances the ability of the benthic community to process refractory organic matter. For this survey Total Nitrogen was a preferred indicator for its simplicity to indicate aerobic or anaerobic conditions and source of organic carbon (Leaching from soil or marine).

Table 6.0: Concentration of Total Nitrogen and OC/TN ratio

Samples	S1	S2	S3
Total nitrogen (mg/100g)	**0.02856**	**0.02716**	**0.02352**
Total Nitrogen expressed as %	**0.02856**	**0.02716**	**0.02352**
Organic Carbon / Total Nitrogen ratio	**9.3**	**7.7**	**10.5**

When the source of Organic Carbon is terrestrial, the ratio of OC/TN is greater than 15 (C/N >15), when the source of OC is marine the ratio of OC/TN is lower than 10 (C/N < 10). For sample S1 and S2 it is clear that the source of Organic carbon was marine while for sample S3 which was closer to the shoreline there can be some mixing from shoreline.

3.2.5 Total Phosphorous

The occurrence of phosphorus in the oceans is in the form of dissolved and inorganic phosphate as well as dissolved organic phosphorus compounds. In fact, the forms of phosphate (orthophosphate, metaphosphate and organically bound phosphate) occur in living and decaying organisms as free ions. They are also found to be either chemically bound in aqueous systems or chemically bound to sediment. It is important for the nutrient to have a threshold value so that there is optimum productivity. At 3.5% salinity, sea water has been found to have a composition of $8.8x10^{-5}$ g/kg of phosphorus. An increased availability of phosphorus would lead to eutrophication and reduced calcification, hence destabilizing the ecosystem. On the other side, a reduced amount of phosphorus in sea water will cause the growth rate of phytoplankton to become dependent upon the phosphate concentration. Furthermore, the sediment plays an important role in the overall nutrient (phosphate) dynamics in estuaries and closed systems like barachois. During a normal state, a certain amount of phosphorus entering the shore is retained in the sediment. The net retention of phosphate in the sediment would be the difference between the two extreme opposite directed flux rates; (a) the downward flux caused by sedimentation of particles entering the sediment (b) the upward flux generated by decomposition of organic matter.

Table 7.0: Concentration of Total Phosphorus

Samples	S1	S2	S3
Final concentration (µg/mL) in 25g sediment	**1.25**	**3.91**	**2.31**
Final concentration expressed as mg/Kg	**0.05**	**0.16**	**0.09**
Final concentration as g/kg	**$5x10^{-5}$**	**$1.6x10^{-4}$**	**$9x10^{-9}$**

The total phosphorous values are within the threshold levels in the sediment and indicate a balanced ecosystem far from eutrophication and atrophic conditions.

3.2.6 Heavy Metals

Parameters	Units	Results
Arsenic, As	ppm	1.57
Cadmium, Ca	ppm	1.44
Chromium, Cr	ppm	6.85
Copper, Cu	ppm	2.23
Iron, Fe	ppm	7.45
Lead, Pb	ppm	4.46
Manganese, Mn	ppm	3.23
Nickel, Ni	ppm	5.63
Zinc, Zn	ppm	1.93

Heavy metals exist naturally in the environment due to mineral weathering. Other sources of heavy metals include industrial activities like manufacture of metallic products, chemicals, agricultural run-offs which contain fertilizers, inappropriate waste disposal and also leisure activities (Nasser., 2013). Further tests should be conducted in the barachois periodically and with more sampling around to ensure a reliable data and constant monitoring. Filter-feeder marine organism's aquaculture is directly related to heavy metal bio-accumulation. To ensure a safe product, a vigorous monitoring plan should be set-up given that the barachois is surrounded with human habitation, agricultural lands and commercial activities.

3.3 Marine Biodiversity

3.3.1 Algal diversity

As per our survey algae diversity comprised mostly of *Gracillaria sp* (red algae). This was the most dominant algal species and covered maximal live benthic cover. Though this red algae species is not being commercially exploited in Mauritius for now, it has over the years been under pilot studies by the Mauritius Research Council for commercial exploitation. Other than this species other algal species was rarely encountered. Common Mauritian green algal species (cholorophytes) and brown algae (pheophytes) usually need a hard substratum for growth, but with such a high silt deposition most of the available rubbles would have sank in the sediment. Gracillaria colonies form rigid networks of tubular thalli that lie on the sediment and thus easily thrive over this ecosystem without any hard substrate requirement. In the barachois, those common species were only found on the hard rocky substratum found near the rock barriers.

3.3.2 Invertebrate diversity

The most commonly encountered groups of invertebrates include: sponges, crustaceans, molluscs (bivalves and univalves), echinoderms (sea cucumbers), annelids (sea worms) and coelenterates (jellyfish).

Sponges: The most common sponge species encountered were *Tethya robusta* (spherical in shape) *Axinyssa topsenti* and *Clathria frondifera*. Of these sponges *C. frondifera* was the most abundant and was found as patches over the sediments.

Crustaceans included crab species such as *Pilumnus verspertilio* (spider crab) and *Uca annulipes*, sea anemones such as *Aiptasia spp* and the common inverted jellyfish, *cassiopea sp*. Common shrimps were also found abundant near the mangrove areas. One barnacle species (*Chelonibia testudinaria*) was encountered on few rocks around barachois.

Of the molluscs encountered the following univalves were common: *Monetaria annulus* and *Planaxis sultanus* were very common. Edible species like “Kono Kono” were not encountered in this region, because these species usually prefer reef areas with ample algal cover. The most common bivalves were, *Gafrarium pectinatum, Tellina madagascarenis* and

Ctenoides scaber. The first 2 species mentioned are edible and are collected by locals for consumption. These bivalves usually burry in the sediments and are dug out by local fishermen.

3.2.3 Fish Species Diversity

With a closed system over the years and a diminishing depth with high level of silt deposition fish species diversity should have gradually decreased. The common fish species encountered during our survey include the common *siganus sp* (cordonnier), *Upeneus sp* (rouget), *Valenciennea sp* (cabot), *Mugil cephalus* (Mullet). Herbivorous fish such as *Siganus sutor* (rabbit fish), *Naso unicornis* (corne) and *Acanthurus sp* (surgeon fish) which were once common in the region were not encountered most probably because of the lack of algal growth. These herbivorous fish eat green algae such as *Enteromorpha sp*, *Ulva lactuca* as well as brown algae such as *Sargassum sp* as their diet.

3.2.4 Crab Density

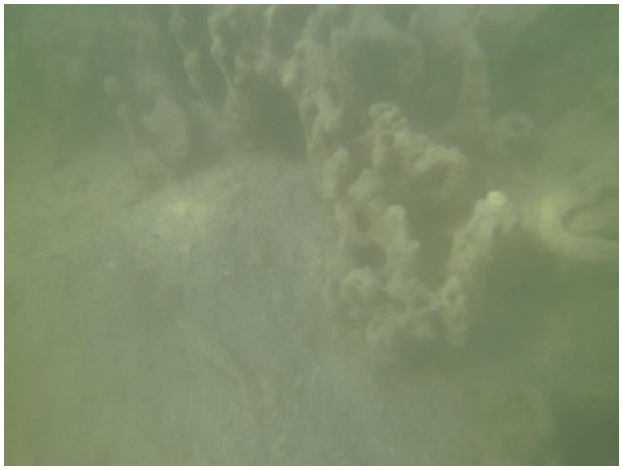
Crab density in an area indicate ecosystem richness and sustained hood webs. More than 30 random quadrats ($1m^2$) were placed along the shoreline lines. The first set ran from along the left side of the shoreline while the second set was on the right side and included the mangrove forest on the small islet. It was worth noting that some of the shorelines were extremely rocky (islet). For the first set minimal value was 2 per m^2 while the maximal was 57 per m^2 and an average of 22 per m^2. The minimal values of crab holes per quadrat corresponded to rocky shorelines. For the second set including the islet the minimal value recorded was 7 per m^2 while the maximal was 69 per m^2 and an average of 31 per m^2. These values indicate a healthy marine ecosystem for this species of crab.

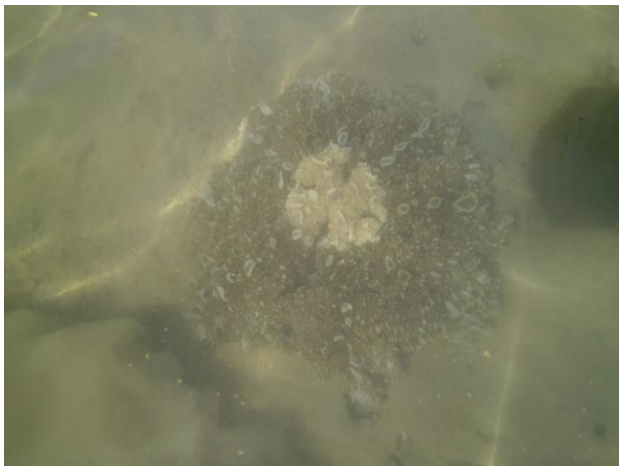
3.2.5 Coral Species

The coral species found during the survey were: *Porites lutea*, *Cyphastrea microphthalma*, *Porites rus* and *Montipora calcarea*. *Porites lutea* were the most dominant species to be found. They were large and found mainly near the rocks on the northern part of the barachois. The low density of coral species and cover is due to the very shallow water depth and mostly sandy bottom. The coral recruit survey also revealed only one small recruit of 1mm with the flashing blue light. Therefore, indicating that the area is not appropriate for coral to grow.

3.2.5 Representative pictures in and around the barachois

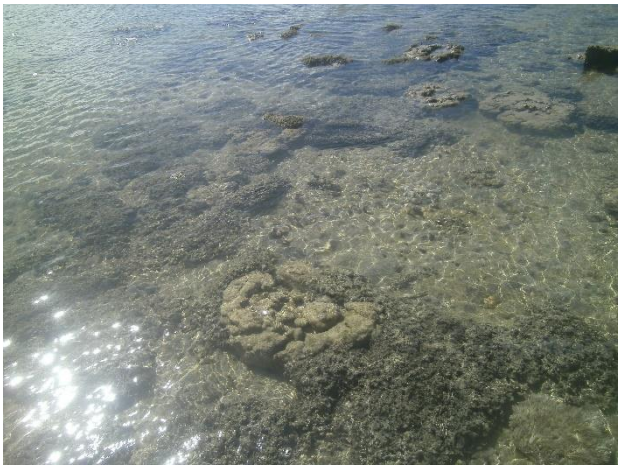





















4.0 Conclusion and Recommendation

Being very shallow at low tide (maximum water depth of 1m in the middle of the barachois), we find that this ecosystem is very limited in terms of diversity of marine organisms. In regards to an integrated aquaculture, it would best fit for culture of edible oysters using cages. Edible molluscs such as clams are available in the sediment and can be harvested in a sustainable way in patches (segmented areas). While one patch is harvested the other areas are left to grow for a sustainable catch. Culture of crabs in cages is possible as there are mangroves of both species (*Rhizophora mucronata* and *Bruguiera gymnorhiza*) around the barachois, but care would have to be taken due to the sediment quality which is highly clay and silt. Culture of herbivorous fish following larval ranching is not advisable due to the low patches of macroalgae in this area. Nevertheless, these fish can be cultured if enough substratum (rocks) are placed to allow more green algal growth or artificial feeding is supplied. For carnivorous fish such as groupers and sea breams the first thing to deal with would be the depth. Through proper sand removal or dredging, depth of the area can be increased, but that would greatly increase the costs of investments. High density of shrimps was also observed along the islet near the mangrove shores. This indicates that the environment is good for crustaceans. The area if properly managed and with clear investments in specific aquaculture projects can be lucrative, but the choice of species would be critical. Since the area is open on all sides, there is also a high risk of tampering with amenities set for aquaculture.

5.0 References

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Annex 1

The following guidelines are published for the information of the public with regards to coastal water quality requirements for various activities around the Republic of Mauritius.

The Mauritius Government Gazette *30 April 1999*

General Notice No. 620 of 1999

MINISTRY OF ENVIRONMENT, HUMAN RESOURCE DEVELOPMENT & EMPLOYMENT

Department of Environment

Guidelines for coastal water quality

The following guidelines are hereunder published for the information of the public with regards to coastal water quality requirements for various activities around the Republic of Mauritius.

Classification	*Principal Beneficial uses/objectives*
Category A – Conservation	
Class A1 – Conservation of coral community	A1 – Conservation of coral community
Class A2- Conservation of natural areas	A2 – Conservation of natural areas such as mangroves, sea grass, wild life habitat and marine spawning, nursing and feeding grounds.
Category B – Recreation	
Class B1 – Primary contact	B1 – Water sports like swimming, diving, surfing where there is direct contact.
Class B2 – Secondary contact	B2 – Water sports such as boating, fishing and other activities involving less body contact or where direct contact with water may occur but the probability of body immersion is minimal.
Category C – Fisheries	
Class C1 – Aquaculture	C1 – Propagation of marine life such as fish, crabs, shrimps, and other marine fauna.
Class C2 – Shellfish	C2 – Culture of shellfish – oysters, mussels, clams.
Category D – Industrial	
Class D – industrial and others	D – Natural water resources used as a receiving water body for industrial and agricultural discharges (harbour, power station and other industrial activities). There should be no unpleasant odour to people residing nearby.

Each activity requires different water quality and this is indicated underneath:

Category A is meant for the conservation of the coral community and natural areas.

Class A1 is intended for the coral ecosystem and requires seawater quality that will not hamper healthy coral growth.

Class A2 is for the conservation of natural areas as mentioned in the table above and requires a slightly less stringent water quality.

Category B is intended for recreation purposes.

Class B1 defines the water quality needed for sports such as swimming, diving, surfing, etc. where there is maximum body contact with the water. For this class the potential health hazards due to pathogenic microorganisms have been considered.

Class B2 is intended for water sports such as boating, fishing, etc. where there is likely to be minimal body contact with water, and so the quality of the water is less stringent especially with regards to pathogenic micro organisms.

Class C concerns fisheries.

Class C1 is intended for the production of fish, crabs, shrimps, etc.

Class C2 is for the culture of shellfish where the requirements for pathogenic organisms are very stringent.

Category D comprises the remaining coastal areas, which act as receiving body for industrial and agricultural discharges and include the harbour, power generating plants, and other industrial activities. No limits are imposed for pathogenic microorganisms but there should be no unpleasant odour to people residing nearby.

The Mauritius Government Gazette *30 April 1999*

Coastal water quality requirements for various categories

CATEGORY		A Conservation		B Recreation		C Fisheries		D Industrial
Class		A1 Coral Community	A2 Natural Areas	B1 Primary Contact	B2 Secondary Contact	C1 Aqua-culture	C2 Shellfish	D Industrial & others
Parameters	Unit							
pH	-	7.5-8.5	7.5-8.5	7.5-8.5	7.5-8.5	7.0-8.5	7.0-8.5	7.0-9.0
Temperature	^{0}C	ambient	ambient	ambient	ambient	ambient	ambient	ambient
Suspended Solids	mg/l	5	5	5	10	15	15	15
Dissolved Oxygen	mg/l	>5	>5	>5	>5	>5	>5	>2
Chemical Oxygen Demand[1]	mg/l	2	2	3	3	5	5	5
Total Coliforms	CFU[3]/100 ml	1000	1000	1000	5000	1000	70[2]	---
Faecal Coliforms	CFU/100 ml	200	200	200	1000	200	14[2]	---
Nitrate-Nitrogen	mg/l	0.2	0.3	0.8	0.8	0.8	0.8	1.0
Phosphate	mg/l	0.04	0.05	0.08	0.08	0.08	0.08	0.1
Oil & Grease	mg/l	Not detectable by N-hexane extraction method						
Phenol	mg/l	0.05						
Arsenic	mg/l	0.05						
Cadmium	mg/l	0.02						
Cyanide	mg/l	0.01						
Chromium	mg/l	0.05						
Copper	mg/l	0.05						
Lead	mg/l	0.05						
Total Mercury	mg/l	0.0005						

1 by alkaline potassium permanganate method
2 organisms per 100 ml by MPN method
3 CFU: Colony Forming Unit

Date: 16 April 1999

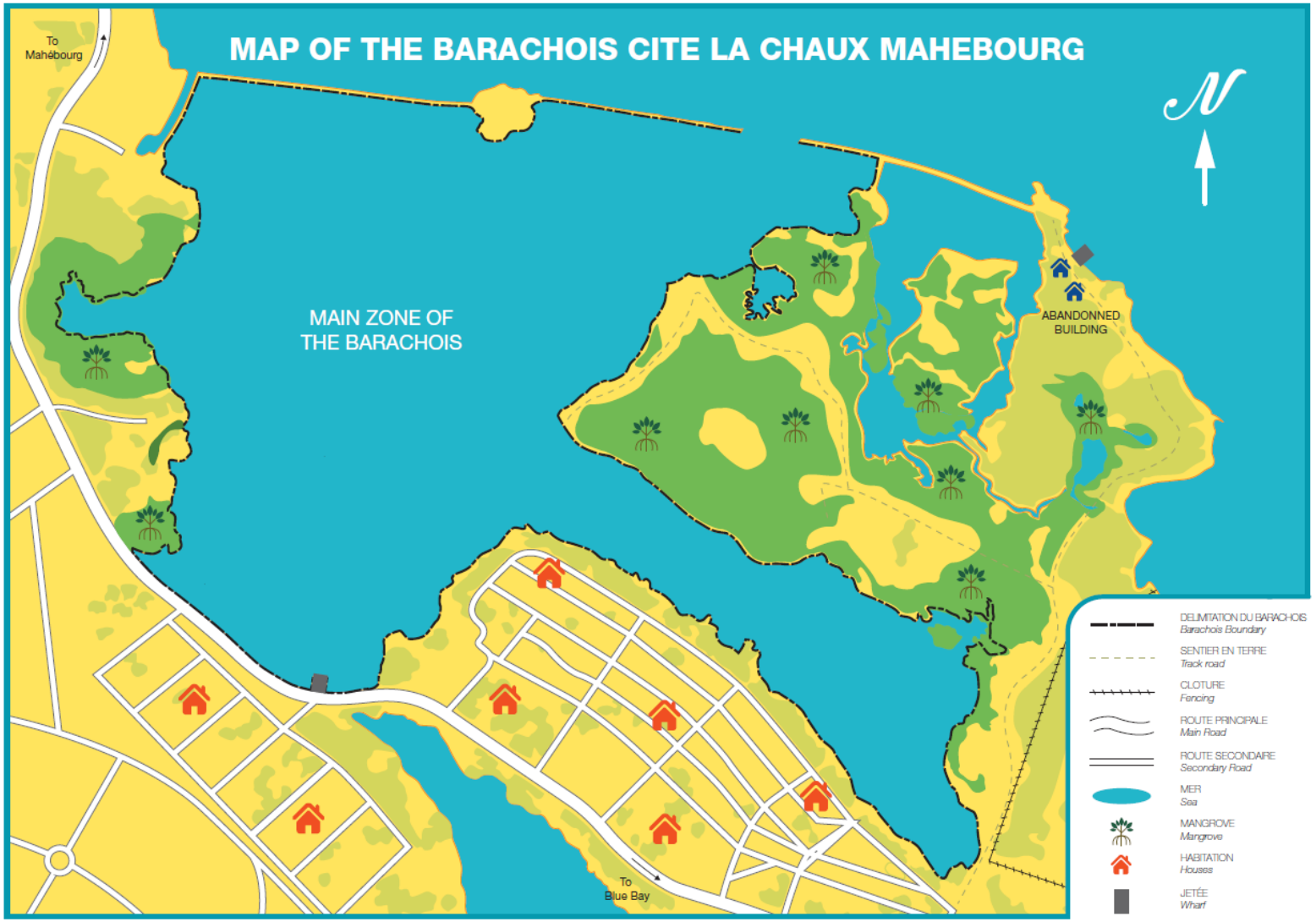
SCHEDULE

(regulation 3)

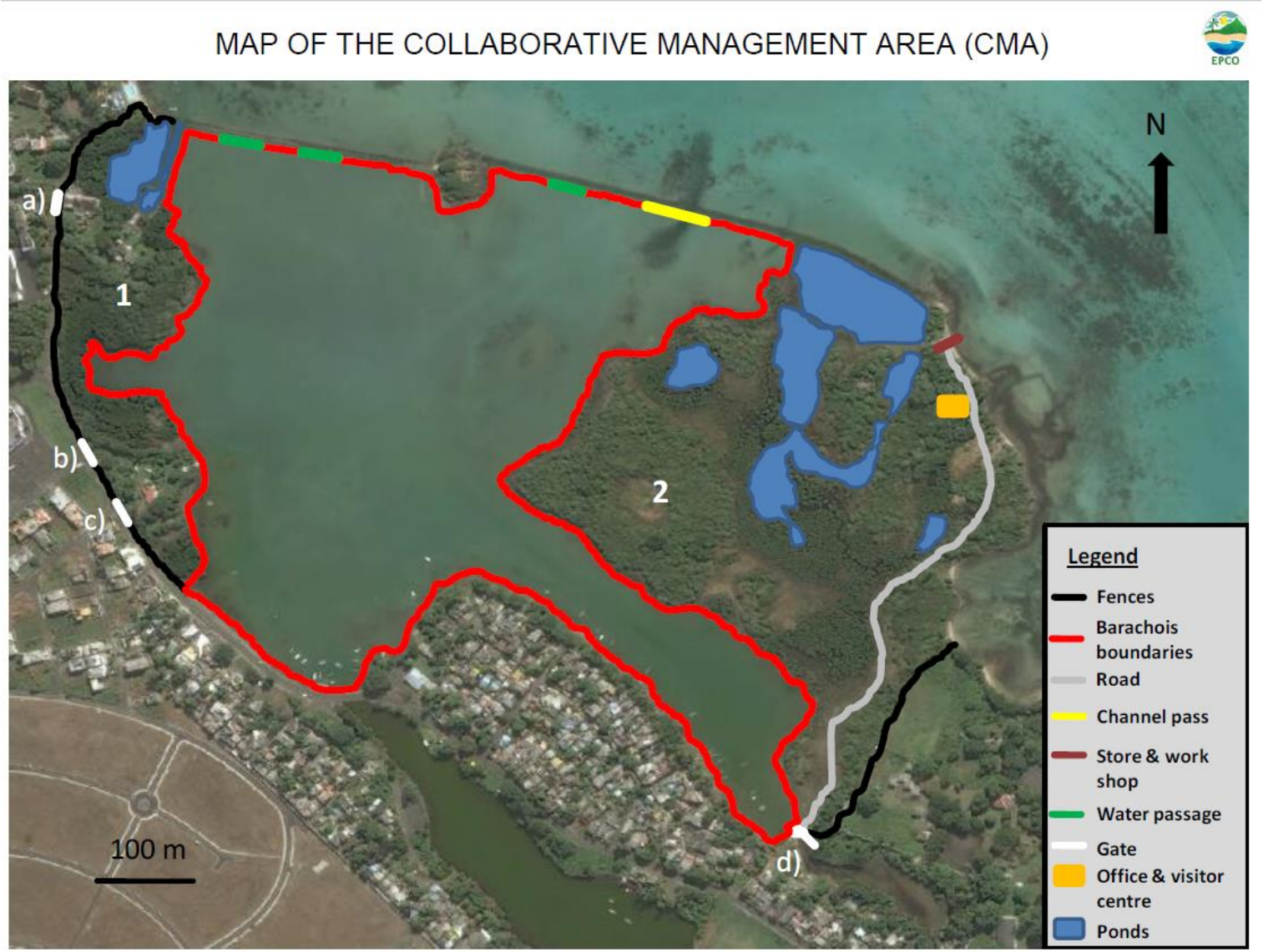
The following standards are permissible limits or range for the corresponding parameters:

Parameter	*Unit*	*Permissible limits*
Temperature	***°C***	***40***
PH	*-*	*5 – 9*
Floatables	*mm*	*6*
Biochemical Oxygen Demand (BOD5)	***mg/l***	***250***
Chemical Oxygen Demand (COD)	*mg/l*	*750*
Suspended Solids	*mg/l*	*300*
Cadmium	*µg/l*	***20***
Chromium (VI)	*µg/l*	*100*
Chromium, Total	*µg/l*	*500*
Cyanides (as CN-)	*µg/l*	*100*
Lead	*µg/l*	*2*
Nickel	*µg/l*	*2*
Zinc	*µg/l*	*2*
Total Mercury	*µg/l*	*10*
Arsenic	*µg/l*	*200*
Total pesticides	***mg/l***	***1***
Oil & Grease	*mg/l*	*20*

Annex 2


MAP OF THE BARACHOIS CITE LA CHAUX MAHEBOURG
To Mahébourg
MAIN ZONE OF THE BARACHOIS
ABANDONNED BUILDING
To Blue Bay
N
DELIMITATION DU BARACHOIS
Barachois Boundary
SENTIER EN TERRE
Track road
CLOTURE
Fencing
ROUTE PRINCIPALE
Main Road
ROUTE SECONDAIRE
Secondary Road
MER
Sea
MANGROVE
Mangrove
HABITATION
Houses
JETÉE
Wharf

Annex 3


MAP OF THE COLLABORATIVE MANAGEMENT AREA (CMA)
EPCO
N
a)
b)
c)
d)
1
2
100 m
Legend
Fences
Barachois boundaries
Road
Channel pass
Store & work shop
Water passage
Gate
Office & visitor centre
Ponds